A Self-Calibrating Distributed Acoustic Sensing Platform*

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Abstract

We will demonstrate the operation of the Acoustic Embedded Networked Sensing Box (ENSBox), a platform for prototyping rapid-deployable distributed acoustic sensing systems. The ENSBox is a Linux-based acoustic sensing system with and integrated, high precision self-calibration facility sets it apart from other platforms. This self-calibration is precise enough to support acoustic source localization applications in complex, realistic environments: e.g., 5 cm average 2D position error and 1.5 degree average orientation error over a 80x50 m outdoor area.

Categories and Subject Descriptors

C.3 [**Computer Systems Organization**]: Special-Purpose and Application-Based Systems—*Signal-processing systems*

General Terms

Algorithms, Design, Experimentation, Measurement

Keywords

Self-localization, Distributed Acoustic Sensing

1 Introduction

Distributed acoustic sensing has many applications in scientific, military, and commercial applications, including population measurement projects tracking the calls of birds [4] and wolves, military systems tracking vehicle [5] and personnel [1] movements, and commercial systems in support of smart spaces. However, despite the overall interest in these problems, and despite significant progress in related areas such as source localization theory and sensor network systems, progress toward developing and deploying these applications has been greatly slowed by the absence of an integrated platform suitable for prototype acoustic source localization systems.

To address this need, we have developed the Acoustic Embedded Networked Sensing Box (ENSBox), a platform for prototyping rapid-deployable distributed acoustic sensing systems. Each ENSBox integrates a developer-friendly ARM/Linux environment with key facilities required for source localization: a sensor array, network services, time synchronization, and self-calibration of array position and orientation. Self-calibration is especially important to source localization applications, because error in the assumed position and orientation of a node introduces error into the location estimate of an acoustic source, and a careful manual survey is very time-consuming.

The details of the implementation and testing of the Acoustic ENSBox and its self-calibration facility can be found in [3]. In this demonstration, we will show how the system operates, in particular demonstrating the self-calibration system, resolving the location and orientation of the arrays with high accuracy, despite long distances between nodes and background noise. We will demonstrate accuracy comparable to prior tests in which we achieved 5 cm average 2D position error and 1.5 degree orientation error over a 80x50 m area.

2 Platform Overview

The Acoustic ENSBox system provides the hardware and software facilities necessary for acoustic source localization applications in a platform that has sufficient resources to deploy systems without extensive optimization. These facilities include a Linux operating environment, a sensor array on each node, sub-sample time synchronization across nodes, network services, and a calibration service to automatically determine the positions and orientations of deployed arrays.

2.1 Hardware and System Software

The Acoustic ENSBox is based on the Sensoria Slauson board, a single board computer based on the 400 MHz Intel PXA255 with 64MB RAM. The node runs the Linux 2.6.10 kernel, and application and other user-space software is written within the Emstar [2] software environment.

Each node hosts a 4-channel microphone array, geometrically arranged as shown in Figure 1. The microphones

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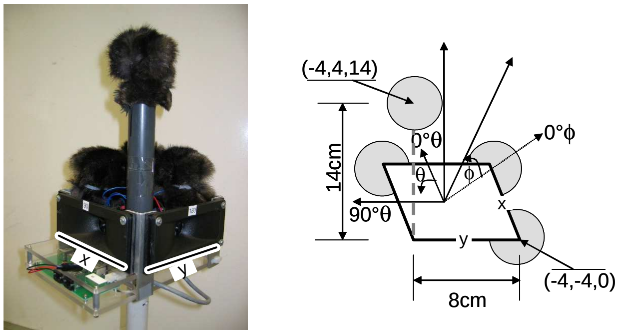

Figure 1. Photograph of an acoustic array, and a diagram of the array geometry. The microphones are laid out in an 8 cm square, with one raised 14 cm above the plane.

are condenser modules (RTI 1207A) coupled with a custom preamplifier board. They are mounted securely in a plastic and aluminum chassis.

The node can be powered from an internal Li+ battery or from an external source such as an adapter, an external battery, or a solar panel. The system will run continuously for 24 hours on a single 12V 7.2 AH (86WH) gel cell.

2.2 Software and APIs

While hardware integration is an unavoidable part of building a platform, the key advantages of the Acoustic ENS-Box platform lie in the software and API stack that we have designed to support our target applications. These include a time synchronized sampling API, network services, and a location and orientation self-calibration service.

The time synchronized sampling API and networking primitives provide very convenient interfaces for source localization algorithms. In recent deployments, we found that these building blocks enabled us to rapidly develop acoustic monitoring applications. However, by far the most critical feature to rapid, low-cost deployment has been the location self-calibration service. With past field recording systems, locating the sensors has been the most difficult part of the deployment, and in many cases the measurements are ultimately approximated. In many environments, the difficulty of acquiring GPS signals or even line-of-sight between nodes makes accurate localization by survey techniques practically impossible.

The self-calibration service uses audible acoustic ranging to determine the 3D location and orientation of the sensor arrays in the system. Each node emits an audible coded signal, or “chirp”, in a round-robin sequence. Based on the reception time of each “chirp”, neighboring nodes estimate the range and bearing to each transmitter in turn. The wide-band design of the ranging system yields long effective ranges and high resilience to acoustic interference and partially obstructed line-of-sight.

The range and bearing information is published back over the network to a central node that computes and displays a coherent coordinate system. The centralized algorithm uses outlier rejection heuristics to improve the position estimates and then fits the resulting map to one or more supplied survey points. In outdoor tests this service achieves very high precision, with average 2D position error of 5 cm in an 80x50 m urban environment, and with average orientation errors of 1.5 degrees.

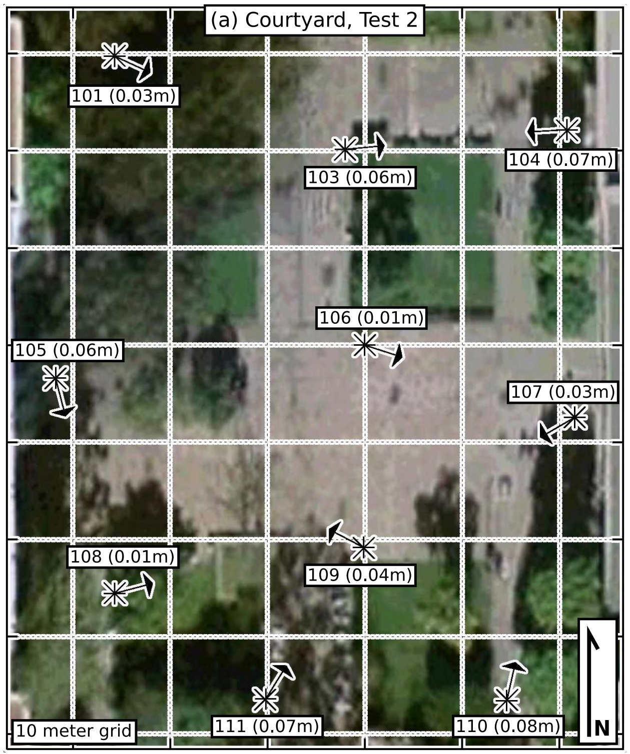

Figure 2. Shows the experimental setup for one of our courtyard test deployments. Ground truth node locations are indicated by the X’s. The ‘+’ and arrow indicates a position and orientation estimate from our system, and the 2D position error in m is shown in parentheses. Overhead courtyard image courtesy of Google Earth.

3 What you will see

In our demonstration we will have 5 nodes covering a large area performing and displaying the results of the self-calibration service. Using a web browser, we will initiate localization and verify that the output matches the test deployment. In this demonstration we will try to push the limits of the system in terms of range, although for logistical reasons we will not be able to demonstrate a large number of participating nodes.

4 References

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